DYNAMIC MODULUS TESTING FOR A NEW SOUTH AFRICAN MECHANISTIC PAVEMENT DESIGN METHOD

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A revision of the South African mechanistic-empirical pavement design method is in progress. The revision requires improved and revised test protocols for advanced characterization of hot-mix asphalt (HMA). The revision is funded by the South African National Road Agency Limited (SANRAL) and the CSIR project. As part of the project, the CSIR through Strategic Research Panel (SRP) funding is conducting a research study to develop advanced laboratory test protocols to characterize the mechanical properties of HMA. This paper presents dynamic modulus test protocol developed to support the design method. A full scale laboratory tests were conducted on continuously graded HMA with 60/70 penetration grade binder (standard South Africa HMA mix) to develop the dynamic modulus test protocol. The required modifications of the protocol will be finalized and some potential challenges with the adoption will be addressed after more data becomes available for validation. This dynamic modulus protocol is applicable to South Africa HMA mixes and other asphalt mixes with similar characteristics.

Key Words : *dynamic modulus, hot-mix asphalt, continuously graded mix, master curve, pavement, mechanistic-empirical*

1. INTRODUCTION

The South African National Road Agency Limited (SANRAL) is developing a new mechanistic-empirical pavement design guide for flexible road pavements. The design guide, which is now known as the South African Pavement Design Method (SAPDM) will use dynamic modulus as the elastic property for resilient response characterization of HMA.

Over the years, several test procedures have evolved from the original dynamic modulus test procedure developed by American Society of Testing and Materials (ASTM) in the early 1970s[1]. The National Cooperation of Highway Research Program (NCHRP) Mechanistic-Empirical Pavement Design Guide (MEPDG) has recommended the American Association of State Highway and Transportation Officials (AASHTO), provisional protocol[2] to determine dynamic modulus for flexible pavement analysis, and an alternative test method is the AASHTO T320[3] .

The NCHRP is also developing so-called simple performance tests , which includes dynamic modulus test protocol through projects 9-19 and 9-29 to verify performance characteristics of Superpave mix designs[4),5)].

Dynamic modulus is a stiffness parameter used mainly to characterize behavior of HMA materials under varying temperature and loading frequencies. The theory behind dynamic modulus is well documented through several studies[6)-9)]. In these studies, the values of dynamic modulus obtained from maximum stress and strain of cyclic loading tests are used as performance criteria for HMA mixes over a range of field loading frequencies and temperatures. Thus, dynamic modulus properties have been extensively studied to describe behavior of HMA mixes. However, no laboratory test protocol/procedure or set of data is currently available to determine dynamic modulus properties of HMA mixes in South Africa. Instead, the existing

South African mechanistic design method (SAMDM) for flexible pavements uses resilient modulus to characterize the elastic behavior of HMA mixes at temperatures of 20°C and 40°C[10].

For a typical South African continuously graded (dense graded) HMA mix, the SAMDM recommends maximum elastic moduli based on different HMA layers in the pavement. At the test temperature of 20°C and loading frequency of 10Hz, resilient modulus values range from 6000 MPa at the surface (0 mm) of the pavement to 9000 MPa at the depth of 250 mm. At temperature of 40°C, the recommended maximum resilient modulus value is 7500 MPa, and the minimum value is 2200 MPa at 10Hz.

Several shortcomings were found in the methodology used to obtain resilient modulus as a parameter selected to characterize HMA mixes in the 1986 AASHTO Pavement Design Guide. To properly characterize modulus and deformation characteristics of HMA mixes under dynamic traffic loading, laboratory tests should closely simulate realistic temperature and time rate of loading, i.e., frequency (related to field trafficking speeds). Thus, a new testing protocol that is based on actual pavement conditions in South Africa, including wide range of temperatures and loading frequencies is needed to characterize HMA mixes for use in the new South African mechanistic pavement design method.

Dynamic modulus testing provides data that covers a range of test temperatures and loading frequencies for proper characterization of asphalt mixes. Viljoen[11] reported that the minimum asphalt surface temperatures in South Africa is generally about 5°C and in few instances drop below 0^{o}C, whereas the maximum surface temperature is generally between 45°C and 55°C although it can reach close to 70°C in only few days of the year.

This paper focuses on dynamic modulus test protocol developed for HMA characterization for a new South Africa mechanistic-empirical flexible pavement analysis. The overall objective was to develop and validate laboratory test protocol for measuring dynamic modulus of HMA mixes in South Africa. A comprehensive laboratory testing program was conducted on a standard South Africa HMA mix (i.e., continuously graded HMA with a 60/70 penetration grade binder) to develop the dynamic modulus test protocol. The results from the laboratory testing program were used to construct a master curve to model time-temperature dependency of the mix tested, and to provide guidelines of HMA dynamic modulus modeling for the SAPDM.

2. MATERIALS AND MIX DESIGN

(1) Materials and properties

The hot-mix asphalt used for this study is continuously graded (dense graded) mix with a maximum aggregate size of 13.2mm. The mix was manufactured according to South Africa standards (TMH5: Sampling Methods for Road Construction Materials). The raw materials (aggregate and binder) were sampled at the asphalt plant in accordance with TMH5. The aggregate used was a 100% crushed dolorite with mine sand, and lime stone dust filler. **Table 1** shows the grading analysis results of the aggregate.

The bulk relative density (specific unit weight) of the aggregate was 2.912 g/cm^3, the water absorption was 0.42%, sand equivalent of 78 and flakiness index of 12.3. The bitumen was a 60/70 penetration grade binder with penetration (25°C, 100g, 0.1mm) of 64, and softening point after Rolling Thin Film oven (RTFO) aging at 49°C.

Typically some characterization of the bituminous binder used for the protocol development would be expected. However, this was not the case for this study because the purpose was not to evaluate the binder but instead to evaluate the test procedures for HMA mixes in South Africa.

Table 1 Aggregate grading

Sieve size (mm)	Percent passing
13.2	100
9.5	99
6.7	88
4.74	68
2.36	45
1.18	30
0.600	21
0.300	16
0.15	9
0.075	5.5

(2) Mix design

The hot-mix asphalt mix used for the dynamic modulus test protocol development was obtained from an asphalt plant in South Africa. The mix design was done by the asphalt plant based on the Marshall mix design method. The mix design results indicated an optimum binder content of 4.9%, and air voids content of 5% to produce a continuously graded (dense graded) asphalt mix with a 60/70 penetration grade binder. The production (mixing) and compaction temperatures used to manufacture the mix were 150°C and 135°C, respectively.

(3) Mix sample preparation

A loose continuously graded HMA mix with 60/70 penetration grade binder was obtained from the asphalt plant. As mentioned earlier, the mix was manufactured at the mixing temperature of 150°C and compacted at 135°C for the preparation of the test protocol specimens. Samples were prepared at the design air voids content of 5% using a design binder content of 4.9%. The AASHTO gyratory compaction procedure was adopted for this protocol. Details of gyratory compaction procedure for cylindrical specimens can be found in the AASHTO T312[12)].

A short-term aging was performed on the loose asphalt mix from the plant before any compaction took place using the Superpave short term aging procedure. The purpose was to simulate the aging that takes place during the production process in the asphalt plant and placement in the field. The short-term aging method, as described by Von Quintus et al. [13)], consists of placing the prepared loose mix back into the oven for 4 hours at 135°C before compaction. In this study, the mix was aged in open pans in a standard forced ventilation laboratory oven.

A Superpave Servopac gyratory compactor designed and manufactured by the Industrial Process Controls (IPC) Company in Australia was used to produce cylindrical specimens. Loose asphalt samples were compacted to cylindrical specimens of height of 170mm and a diameter of 150mm, and close to 8% air voids, i.e., +3% above the target (design) air voids content of 5%. A trial and error method was used to obtain the excess air voids content of +3%. The aim was to obtain target air voids of 5% after the compacted specimen is cored and cut for the dynamic modulus testing. In the dynamic modulus test protocol for SAPDM, samples whose air voids content differ by more than ± 0.5% of the design air voids (5%) are discarded.

A total of ten specimens were compacted to a height of 170mm and a diameter of 150mm for the dynamic modulus test protocol development. After compaction, the specimens were allowed to cool for approximately 10 minutes before extruded from the mould. The extruded specimens were then allowed to cool overnight. The final test specimens were obtained after sawing/cutting and coring to produce dynamic modulus test specimen sizes of 100mm diameter by 150mm high.

4. LABORATORY TESTING PROGRAM

(1) Development of test protocol

The SAPDM requires characterization of South African hot mix asphalt mixes by dynamic modulus property. Considerable number of existing dynamic modulus test methods/procedures were reviewed and used as the basis for developing the dynamic modulus test protocol for SAPDM. The review indicated that due to several limitations in some of the commonly used HMA tests methods, road researchers, agencies, and the industry are currently developing and evaluating HMA test protocols for their local use.

Dynamic modulus tests can be conducted in a uniaxial (triaxial) conditions in compression or under shear conditions. The AASHTO TP 62 (uniaxial) is the provisional test protocol for dynamic modulus testing for mechanistic-empirical flexible pavement analysis. The revised and modified AASHTO TP 62 protocol for South African HMA road pavement conditions was used to conduct laboratory tests on the standard mix with 60/70 penetration grade binder for verification and repeatability purposes.

(2) Dynamic modulus test protocol for SAPDM

The dynamic modulus test protocol described in this paper is similar to the one contained in the AASHTO TP62, except that some modifications were made to suit South African road pavement conditions. A strain controlled instead of stress controlled loading used in the existing dynamic modulus test protocols were used in this protocol for SAPDM. Using this approach, the applied stress on the sample is automatically varied in the test software so that the magnitudes of the strains are always kept within the range of 75 to 125 microstrains in order to ensure linear behavior of the sample.

The test protocol for SAPDM uses Universal Testing Machine with load capacity 25kN (UTM-25). The UTM-25 system has been widely used in major pavement design projects for dynamic modulus testing of hot-mix asphalt mixes, and complies with several international standards (AASHTO TP 62, NCHRP 9-29, and BSI EN 12697-26[13)]). It should be noted that this protocol does not impose a particular type of testing device. The precise choice of the testing equipment and conditions depends on the capabilities of the device and flexibility of the software associated with the testing system.

The recommended test sequence in the AASHTO

TP62 protocol consists of testing a maximum of 2 replicate specimens at temperatures of –10, 4.4, 21.1, 37.8, and 54.4°C, and loading frequencies of 25, 10, 5, 1.0, 0.5, and 0.1 Hz when three LDVTs are used. Based on typical pavement temperature experienced in South African roads, five selected temperatures for the dynamic modulus test protocol proposed for the SAPDM were -5, 5, 20, 40, and 55°C, with loading frequencies of 25, 10, 5, 1, 0.5, and 0.1Hz. Majority of the existing dynamic modulus test protocols including the AASHTO TP62 recommend 2 replicate specimens when three LVDTs are used to record strains. However, 5 replicate specimens are proposed for the SAPDM dynamic modulus protocol to ensure a higher confidence in the test results. In addition, a haversine compressive load pulse is recommended in the test protocol for SAPDM. Note that some dynamic modulus test protocols have proposed use of sinusoidal load pulse for testing.

To achieve equilibrium temperature for samples before testing, dummy specimen with a thermocouple was placed next to the test specimen in the test chamber. This is used instead of the proposed equilibrium times of overnight for test temperatures of -10 and 4.4^{o}C, 3 hours for 21.1^{o}C, 2 hours for 37.8^{o}C and 1 hour for 54.4^{o}C as recommended by AASHTO TP 62.

Fig.1 100mm x 150mm cylindrical test specimens.

Fig.2 Dynamic modulus setup with IPC UTM-25.

(3) Dynamic modulus testing

A commercially available servo-hydraulic UTM-25 at the CSIR advanced pavement materials testing laboratory, designed and manufactured by IPC was selected for the dynamic modulus test protocol development. The UTM-25 test setup includes an integrated windows-based PC software, a separate control and data acquisition system and a temperature environmental chamber, which is capable of controlling the test temperatures of the specimen.

In the protocol development, ten specimens were tested at each loading condition to ensure that they were true replicates and provided comparable results to check variability of test results. The applied stress was varied so that the magnitudes of the strains were limited to approximately 100με in order to ensure linear behavior of the sample. **Figs. 1** and **2** show the dynamic modulus test specimens for the test protocol, and the UTM-25 test setup at CSIR BE pavement materials laboratory.

A haversine load pulse was applied on the 100 mm in diameter and 150 mm high gyratory compacted specimens at five test temperatures and six loading frequencies. That is, a total of 30 tests were conducted on the mix to complete a full factorial dynamic modulus test matrix. In comparison with the existing dynamic modulus test procedures, which require a rest period of 2 minutes during testing to allow specimen recovery before applying the next loading, one minute (60 seconds) rest period was found to be adequate between each frequency run during testing in the proposed protocol for SAPDM. This potentially reduces testing time by about 30 minutes for a full factorial dynamic modulus testing.

The specimen's vertical deformation was determined by averaging the readings of three axial linear variable displacement transducers (LVDTs). Axial stresses and the corresponding axial strains were recorded for the last five load cycles for each test to compute the dynamic modulus of the HMA specimens.

5. TEST RESULTS

The dynamic modulus test results consisted of all the data obtained from 30 tests for the 10 gyratory compacted specimens prepared for the study. Thus, the complete test matrix for the protocol consisted of 300 data sets. It should be mentioned that each dynamic modulus test provides two responses (dynamic modulus $|E^*|$ and phase angle δ) for each combination of five testing temperatures and six frequencies, resulting in a total of 60 responses for each sample tested.

The calculation of dynamic modulus, $|E^*|$ and phase angle, δ is automatically performed by the dynamic modulus test system software. Test data were reviewed and the data quality indicators for each frequency and temperature were compared to typical dynamic modulus values of similar asphalt mixes, especially, in the US. The amount of data reported on the sample is simplified in the test software. For full characterization of the HMA materials, the average values of actual temperature, applied peak load/stress, dynamic modulus, phase angle, the peak strains for each LVDT were captured for each frequency.

In this paper, the average values, standard deviation and coefficient of variation of the test results were reported for the ten specimens tested. Detailed discussion and analyses of the test results is discussed next.

6. ANALYSES AND DISCUSSION OF TEST RESULTS

Dynamic modulus values obtained from laboratory frequency sweep test data are used to construct master curves to characterize the stiffness behavior of these materials over ranges of temperature and frequency[14)]. In linear elastic multi-layer calculations, for instance, the dynamic modulus is generally used as input value for Young's modulus.

The test data used for the dynamic modulus analyses include the time of loading, stresses and strains. For viscoelastic materials, the stress-strain relationship under a continuous sinusoidal loading is defined by a complex number called the complex modulus E^* (ASTM D 3497, NCHRP 1-37A, AASHTO TP 62). The complex modulus has real and imaginary parts that define the elastic and viscous behavior of linear viscoelastic materials. The absolute value of the complex modulus is defined as the material's dynamic modulus. For one-dimensional case of a sinusoidal loading, the applied stress and the corresponding strain can be expressed in a complex form by Eqs. 1a and 1b, respectively.

$$\sigma^* = \sigma_0 e^{i\omega t} \tag{1a}$$

$$\varepsilon^* = \varepsilon_0 e^{i(\omega t - \delta)} \tag{1b}$$

where σ is the applied stress, σ_0 is the stress amplitude; ε is the strain response, ε_0 is the strain amplitude; ω is angular velocity, which is related to frequency by $\omega = 2\pi f$; $f = 1/T$; t is time, and T is period; δ is the phase angle related to the time the strain lags behind the stress. Phase angle is an indicator of the viscous (or elastic) properties of the viscoelastic material. For a pure elastic material, $\delta = 0^o$, and for a pure viscous material, $\delta = 90^o$. Mathematically, dynamic modulus is defined as the maximum (peak) dynamic stress divided by the recoverable maximum (peak) axial strain.

From Eqs. 1a and 1b the complex modulus, $E^*(i\omega)$, is defined as the complex quantity in Eq. 2.

$$E^*(i\omega) = \frac{\sigma^*}{\varepsilon^*} = \frac{\sigma_0}{\varepsilon_0} e^{i\delta} = E' + iE'' \tag{2}$$

The real part of the complex modulus is the storage modulus (E') and the imaginary part is the loss modulus (E''). The dynamic modulus $|E^*|$ is the absolute value of the complex modulus, which is defined mathematically in Eq. 3.

$$|E^*| = \frac{\sigma_0}{\varepsilon_0} \tag{3}$$

(1) Statistical analyses of test results

Table 2 presents the statistical analyses results for the 10 specimens tested. The table shows coefficients of variation (COV) for the 10 specimens used to develop the HMA test protocol. The COV values are comparable to figures reported in the standard dynamic modulus test protocol (AASHTO TP 62-07 2007). Also, the proposed current standard practice for dynamic modulus testing recommended that the COV values for properly conducted dynamic modulus test should be approximately 13%, NCHRP Report 614[15)].

In **Table 2**, the COV values are relatively high for the test temperatures of 40 and 55^{o}C although not too far from the recommended values in the NCHRP Report 614. It should be mentioned that dynamic modulus tests at temperatures above 40^{o}C has associated errors, which has been reported in the literature. For instance, Bhasin et al. [16)] reported COV values of up to about 31% for different asphalt mix at 10Hz and 54.4°C.

Table 2: Statistical analysis results for 10 replicate dynamic modulus test specimens

Temperature (^{o}C)	Statistics	Frequency (Hz)					
		0.1	0.5	1	5	10	25
-5	MEAN $\|E^*\|$ (MPa)	25438	28670	29990	32934	34114	35536
	STDEV (MPa)	1223	1315	1353	1452	1451	2027
	COV (%)	4.8	4.6	4.5	4.4	4.3	5.7
5	MEAN $\|E^*\|$ (MPa)	16958	20678	22236	25963	27436	29421
	STDEV (MPa)	1253	1404	1492	1670	1775	2017
	COV (%)	7.4	6.8	6.7	6.4	6.5	6.9
20	MEAN $\|E^*\|$ (MPa)	5965	8880	10369	14201	16078	18304
	STDEV (MPa)	521	615	662	652	656	1123
	COV (%)	8.7	6.9	6.4	4.6	4.1	6.1
40	MEAN $\|E^*\|$ (MPa)	673	1161	1550	2933	3942	5563
	STDEV (MPa)	97	188	260	473	605	748
	COV (%)	14.4	16.2	16.8	16.1	15.4	13.5
55	MEAN $\|E^*\|$ (MPa)	281	359	419	685	907	1526
	STDEV (MPa)	25	40	51	99	128	258
	COV (%)	8.8	11.1	12.2	14.5	14.1	16.9

Generally, when considering the precision of a test method, it is important to identify sources of variability and express them in terms of repeatability and reproducibility. The accepted practice for determining the precision of a test method is given in the ASTM[17]. This practice recommends inter-laboratory study to establish precision for test methods.

The precision of the dynamic modulus test for South Africa is not yet established. Inter-laboratory comparison tests on commonly used South African HMA mixes are needed to establish precision for the developed test protocol. Repeatability and reproducibility will be determined according to South Africa national standards. The precision results shall be compared with available international results. Currently, no institution or agency in South Africa has dynamic modulus testing equipment for inter-laboratory comparison tests.

(2) Master curve and sigmoidal model

The master curve-sigmoidal function analytical approach for estimating dynamic modulus of asphalt mixtures was employed to analyze test data of the asphalt mix tested , i.e., continuously graded asphalt mix with 60/70 penetration grade binder. It is well known that the behavior of viscoelastic materials such as hot-mix asphalts is dependent on the temperature and time of load (frequency) at which the material is tested. Test data collected at different temperatures are usually shifted relative to a reference temperature, so that the various test data can be aligned to form a single master curve.

Different shifting methods may be used to construct a master curve using time-temperature superposition. In this paper, a sigmoidal function is recommended for SAPDM for construction of master curve. The approach recommended by NCHRP Project 1-37A was modified and used as the procedure for SAPDM. The modifications emanate from different test temperatures used in the proposed dynamic modulus protocol for SAPDM. For instance, a reference temperature of 20^{o}C was used for SAPDM protocol instead of 21.1^{o}C used by MEPDG.

The sigmoidal function in Eq. 4 is generally used to describe master curve of asphalt mixes.

$$\log\left|E^*\right| = \delta + \frac{\alpha}{1+e^{\beta+\gamma\log f_r}} \quad (4)$$

where:

$|E^*|$ = dynamic modulus

f_r = reduced frequency

δ = minimum value of $|E^*|$

$\delta+\alpha$ = maximum value of $|E^*|$

β, γ = shape parameters of the model

The fitting parameters δ and α depend on aggregate grading, binder content, and air voids content. The fitting parameters β and γ depend on the characteristics of the binder and the magnitude of δ and α.

The temperature dependency of the dynamic modulus is incorporated in the reduced frequency parameter, f_r in Eq. 5. The reduced frequency is defined as the actual loading frequency multiplied by the time-temperature shift factor, $a(T)$.

$$f_r = a(T) \text{ x } f \qquad (5a)$$

$$\log f_r = \log f + \log a(T) \qquad (5b)$$

where:

f = frequency, Hz

$a(T)$ = shift factor as a function of temperature

T = temperature

In the MEPDG, shift factors are expressed as a function of the binder viscosity to allow aging over the life of the pavement to be considered using the Global Aging Model developed by Mirza and Witczak[18]. Eq. 6 presents the shift factor relationship used in the MEPDG and followed for the SAPDM.

$$\log a(T) = c\,(\log \eta - \log \eta_{70_{\mathrm{RTFO}}}) \qquad (6)$$

where:

$a(T)$ = shift factor as function of temperature and age

η = viscosity at age and temperature of interest (Pa.s)

$\eta_{70_{\mathrm{RTFO}}}$ = viscosity at the reference temperature and RTFO aging

c = fitting parameter

Recall that a short-term oven aging for 4 hours at 135°C was used to prepare the continuously graded mix. In this condition, the viscosity as a function of temperature was expressed using the ASTM viscosity-temperature relationship given in Eq. 7. The NCHRP Project 1-37A recommends that A/VTS parameters could be obtained from several test procedures of the bituminous binder including dynamic shear rheometer, Brookfield viscosity, penetration grade and softening point. Based on availability of viscosity test setup in most laboratories in South Africa, the A/VTS parameters used in this study were obtained, exclusively from the Brookfield viscosity tests conducted on the 60/70 penetration grade bituminous binder. An RTFO aging values of A (= 10.713) and VTS (= -3.583) obtained from the data analysis were used for the construction of the master curve for the mix.

$$\log \log \eta = A + VTS \log T_R \qquad (7)$$

where:

η = viscosity (Pa.s)

T_R = temperature (K)

A = regression intercept

VTS = regression slope of viscosity temperature susceptibility

By substituting Eq. 6 in Eq. 5, the shift factors can be obtained as a function of A and VTS parameters with Eq. 6 [19]. This relationship is used in the MEPDG, and recommended for the construction of dynamic modulus master curves from laboratory test data in SAPDM.

$$\log a(T) = c\left(10^{A+VTS\log T} - 10^{A+VTS\log(527.67)}\right) \qquad (8)$$

where:

c = fitting parameter

As mentioned earlier, the reference temperature adopted for the SAPDM protocol is 20°C (T_R = 527.67) instead of 21.1°C (T_R = 529.65) used by MEPDG. Thus, the master curve relationship for SAPDM can be is presented as follows:

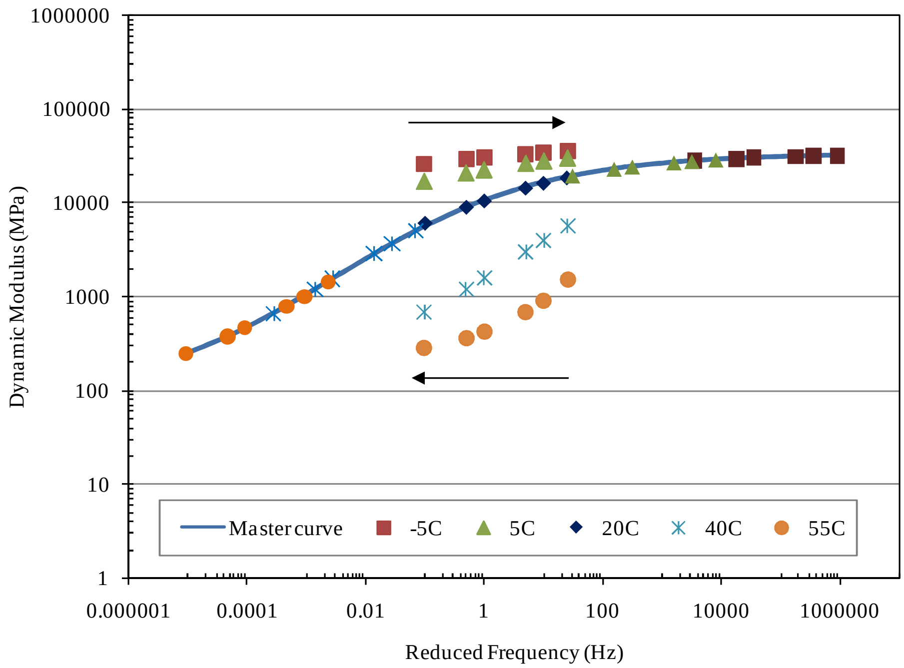
$$\log|E^*| = \delta + \frac{\alpha}{1 + e^{\beta + \gamma\left\{\log(f) + c\left[10^{A+VTS\log T} - 10^{A+VTS\log(527.67)}\right]\right\}}} \qquad (9)$$

All the terms in Eq. 9 are defined under Eqs. 5 to 8.

The fitting parameters ($\alpha, \beta, \delta, \gamma$, and c) were determined through numerical optimization of Eq. 9.

Fig.3 presents detailed master curve at five temperatures constructed for the mix using the average dynamic modulus values for the 10 replicate samples of the continuous graded asphalt mix tested. The dynamic modulus master curve shows that the test data obtained at the low test temperatures (-5°C and 5°C) were shifted to the right whereas the high test temperatures (40°C and 55°C) data were shifted to the left to meet the master curve.

It can be seen that the data obtained from the asphalt mix tested at all the test temperatures were properly aligned on the sigmoidal function curve. This indicates that the function encompasses all the temperature and frequency data very well in the model. The model parameters for the continuously graded mix used for the protocol development are also provided in **Fig.3**.



Model parameters	α	β	δ	γ	c
	2.625	-1.451	1.892	-0.581	1.326

Fig.3 Master curve for average dynamic modulus values of the mix tested

7. SUMMARY AND CONCLUSIONS

There is a general interest in developing dynamic modulus test protocols for proper characterization of elastic behavior of asphalt materials in South Africa. Dynamic modulus test provides elastic modulus values which can be used to predict stress levels in HMA pavements. The current mechanistic-empirical pavement design method in South Africa uses resilient modulus of the asphalt mix at one loading frequency and two test temperatures for analysis.

Currently, no dynamic modulus test protocol is available in South Africa. The revision of a new South Africa mechanistic-empirical pavement design method requires the use of dynamic modulus instead of resilient modulus as the elastic modulus property for asphalt mixes for analysis.

This paper presented the dynamic modulus test protocol developed for the new South African pavement design method using a continuously graded asphalt mix with 60/70 penetration grade binder. Based on the material presented in this paper, the following conclusions can be made:

(a) Development of a modified dynamic modulus test procedure that is based on typical road pavement conditions in South Africa has been successful. This will replace the existing resilient modulus to characterize elastic behavior of asphalt materials in South Africa;

(b) Sigmoidal model can best describe the master curve of the continuously graded asphalt mix tested. In addition, direct laboratory |*E**| test results correlated well with the |*E**| values obtained from the master curves. This finding demonstrates that the master curve encompasses the temperature-frequency effects of the asphalt mix tested such that the model parameters obtained can be used as the basis for other South African asphalt mixes with similar characteristics;

(c) Statistical analyses in terms of mean, standard deviation and coefficient of variation, conducted on the data obtained from this study provides justification for SANRAL materials cluster subcommittee on asphalt materials to approve the dynamic modulus protocol for use by SAPDM. The final test protocol will be recommended as technical methods/guidelines for advanced road pavement materials testing in South Africa.

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